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AUGMENTING U.S. ARMY WARRANT OFFICER EXPERTISE
WITH EXPERT SYSTEMS

A research project submitted to the faculty of
San Francisco State University
in partial fulfillment of the
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degree

Master of Science in Business Administration

by

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CERTIFICATION OF APPROVAL

I certify that I have read AUGMENTING U.S. ARMY WARRANT OFFICER EXPERTISE WITH EXPERT SYSTEMS by Georgia Johanna Solseth, and that in my opinion this work meets the criteria for approving a research project submitted in partial fulfillment of requirements for the Master of Science in Business Administration degree at San Francisco State University.

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ABSTRACT

AUGMENTING U.S. ARMY WARRANT OFFICER EXPERTISE WITH EXPERT SYSTEMS

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The purpose of this project was to determine whether automated expert systems can be effectively used to augment the diminishing knowledge base of personnel, intelligence and supply warrant officers in order to keep valuable and needed expertise within the U.S. Army. Based upon secondary research, a model describing the selection criteria for expert system applications was developed. This model, called the Expert System Application Criteria Model (ESAC) , outlined the decision-making thinking processes, the characteristics of the decisions, and the generic functions inherent in successful expert system applications. A survey, with questions designed to measure the variables indicated, was sent to personnel, supply and intelligence warrant officers. Using summary statistics, a profile for each warrant officer type was developed and compared to the ESAC model. It was concluded that expertise used by intelligence warrant officers was not suitable for expert system application. Supply and personnel warrant expertise are prime candidates for expert system applications but will require additional research before expert system augmentation is accepted. (KR)

I certify that the Abstract above is a correct representation of the content of this research paper.

Supervising Instructor	Date

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PROBLEM DEFINITION AND STATEMENT

Organizations are constantly facing a tremendous concern - the drain or loss of valuable and essential resources needed to accomplish their goals. Fortunately, most resources can be readily substituted and replaced. When a firm does not have enough manpower to complete a task, more individuals are hired. When a company has insufficient funds to undertake a new project, a loan may be granted or company assets sold. Countries are looking to and, in many cases, utilizing alternate energy forms to replace finite fossil fuel sources. Although not always simple or inexpensive, there are usually systematic and proven methods and approaches to replacing limited resources.

Because of its unique characteristics, there is one resource, however, presenting some difficulty in effectively replacing. This resource is the human expert. An expert can be defined as [1]:

> "A person who, because of training and experience, is able to do things the rest of us cannot; experts are not only proficient but

[1]P.E. Johnson,"What Kind of Expert Should a System Be?" THE JOURNAL OF MEDICINE AND PHILOSOPHY, Volume 8, 1983: 77.

also smooth and efficient in the actions they take. Experts know a great many things and have tricks and caveats for applying what they know to problems and tasks; they are also good at plowing through irrelevant information in order to get at basic issues, and they are good at recognizing problems they face as instances of the types with which they are familiar. Underlying the behavior of experts is the body of operative knowledge termed expertise."

The experience and know-how developed through years of working in a particular area are the elements which hinder the simple replacement of experts. In addition, the quantities of true experts in a given field are generally limited, making replacement or substitution difficult. If the amount or quality of expertise within an organization diminishes, the organization could potentially lose a valuable and essential asset needed for the organization to function. Such a problem is currently facing the United States Army.

PROBLEM STATEMENT

The United States Army is a vast, bureaucratic establishment with many facets. This service must coordinate extensively with many internal and external organizations to ensure that it can economically and efficiently feed, bed, clothe, maintain, arm, and medically take care of itself. In order to do this effectively, the U.S. Army has warrant officers.

Warrant officers are the Army's technical experts. They are soldiers, who having spent numerous years employed in a particular

field, have gained tremendous amounts of experience and knowledge valuable and necessary to the United States Army. As a result, their expertise is rewarded by promotion to warrant officer. Their knowledge and skills are in such areas as medicine, supply procurement and movement, maintenance, personnel, military intelligence, and other logistic and support operations. For example, their technical expertise ensures that wounded and sick soldiers are properly diagnosed and treated, supplies are received and distributed as needed, and trucks, weapons, communications gear and other equipment remain operational. They provide the necessary expertise, recommendations, and knowledge to assist new soldiers in their development as future experts and to advise senior officers in making sound strategic and operational plans. In essence, warrant officers and their expertise are essential to maintaining combat readiness within the U.S. Army and are key elements in ensuring its effectiveness and success.

Unfortunately, the Army's knowledge base of expertise, the warrant officer, is diminishing and, as a result, so is the combat effectiveness of the U.S. Army. Colonel Michael Moseley, Chief of the Warrant Officers Division, states, "The numbers of warrant officers in the United States Army are lower now than they have been in many years and I don't expect the situation to improve. Authorization levels continue to be reduced in all areas." [1]

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[1]Micheal Moseley, COLONEL, U.S. Army, Telephone Interview, 20 Feb. 1990.

BACKGROUND INFORMATION

The reduction in the number of authorizations of warrant officers and, therefore, the amount of available expertise, can be attributed to three major events. Currently there are strong political and economic pressures within the United States to reduce the national deficit. These pressures have lead directly to the need for defense spending cuts. The military's response to this has ranged from projected base closures to reduction of overall active-duty personnel strength. Unfortunately, included in these strength reductions are the amount of warrant officer authorizations. Fewer warrant officers result in less amounts of available technical expertise.

Closely related is the changing role of the United States Army. The Army is undergoing major structural changes in response to the dramatic moves toward democracy taking place throughout the world. This changing role has lead concerned citizens to question the need for an army as it now exists. As a result, additional political and social pressures are causing a push toward reductions in the U.S. defense posture and associated spending. Again, cuts would lead to personnel reductions and the problem discussed in the previous paragraph is amplified.

The final event effecting the quantity of expertise has been the expanding role of warrant officers from technical experts to leaders and managers. Four years ago, warrant officers were strictly technical advisors and assistants, whereas commissioned officers were responsible for providing the role of leadership and management. Commissioned officers utilized the expertise provided

by warrants to lead more effectively. In 1987, warrant officers were given the option of becoming commissioned officers and thereby assuming the additional role of a leader of soldiers. Approximately ninety percent of all warrant officers are now commissioned[1]. Although this statistic is advantageous in terms of the warrant officers' professional development and the army's supply of leaders, it indicates that significantly less time is available for experts to spend on technical matters. The additional responsibility of leading and managing soldiers has made the already overburdened technical system even more so.

According to COL Moseley, this diminishment of the Army's knowledge base will have severe negative repercussions, most immediately in the personnel, military intelligence, and supply areas where severe shortages already exist [2]. *In peacetime*, the expertise of warrant officers saves money and time by ensuring that the logistics and support systems run smoothly and effectively. In wartime, the expertise saves lives. If this expertise was not available or even began to diminish, as it appears is currently happening, the United States Army would lose numerous resources, the most valuable of these being human life.

RESEARCH PAPER PURPOSE

Unfortunately, there appears to be no easy solution to this problem. The warrant officers' years of experience and familiarity

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[1] Richard Farrant, Chief Warrant Officer Four, Personal Interview, 13 Feb. 1990.

[2] Moseley

with the military system do not make them an easy asset to simply replace with another individual. Indeed, since authorizations for warrant officers are not being eliminated entirely, completely replacing them may not be required. What appears to be needed is a means of augmenting their expertise that would increase or, at a minimum, stabilize the current quality levels and amounts of expertise.

The purpose of this paper is to examine an information system alternative to determine what solution, if any, is available to the Army to augment the type of human expertise present in warrant officers. I am seeking an information systems solution primarily for two reasons: scope and area of interest. Due to the time limit imposed upon this research project, it is not feasible, or even possible, to examine all the viable alternatives for augmenting human expertise. The scope of possibilities is large, ranging from management techniques to human intelligence development. Therefore, the scope of this project has been narrowed to include only information system alternatives. Additionally, information systems is a subject I am interested in, as well as, a degree I am working towards. It is only plausible that this project involve the research of an information system solution.

I have imposed one additional restriction. Due to the limited scope and time restrictions of this research paper and the vast scope of specific areas of warrant officer expertise, research efforts will be directed towards determining a way to augment human expertise specifically in the critically short areas of personnel, supply, and

military intelligence. A discussion of current approaches to augmenting human expertise follow in the succeeding chapter.

CHAPTER TWO:

TOPIC DEVELOPMENT

Within the past several years, many attempts have been made to emulate or capture a human's reasoning and thinking abilities. "Artificial Intelligence" is the term that has been applied to this study. Artificial intelligence, otherwise known as AI, is a research area focused on producing machines exhibiting behaviors normally associated with human intelligence[1].

One of the most immediately promising engineering outgrowths of artificial intelligence research has been expert systems. An expert system is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require human expertise for their solution[2]. The purpose of expert systems is to augment the decision-making processes of others by capturing and making available the decision-making power of an expert. An expert system can be viewed as a computer-based tool

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[1]Lawrence K. Laswell, COLLISION: THEORY VS REALITY IN EXPERT SYSTEM (Reading: QED Information Sciences, 1989), 8.

[2]V. Daniel Chapman, ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS SOURCEBOOK, (New York: Chapman & Hall, 1989), 26.

that emulates the advise that a human expert would give a decision-maker; the software equivalent of a trusted advisor, a colleague or a second opinion [1].

Major characteristics of expert systems include[2]:

1) the ability to perform at the level of an expert,

2) representation of domain specific knowledge in the manner in which the expert thinks,

3) incorporation of explanatory mechanisms and ways of handling uncertainty into the repertoire of the system, and

4) predilection for problems that can be symbolically represented.

The characteristics of this kind of system suggest that the following key points are necessary for understanding and building any expert system[3]:

1. There must be at least one expert to be the source of the knowledge in the system.

2. The expert know-how and know-what must be recorded in systematic structures such as books, computers, and videotapes.

3. The expert system's rules and methodologies must be accessible so that a user can input his problem data as well as have some form of interactive capability.

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[1]James A. Mecklenberger, "Expert Systems: The Next Technology Breakthrough for Education," FORTUNE, Sep. 1987: 6.

[2]Jay Liebowitz and David A. Desalvo, STRUCTURING EXPERT SYSTEMS: DOMAIN, DESIGN, AND DEVELOPMENT, (New Jersey: Englewood-Cliffs, 1989), 4.

[3]David Bendel Hertz, THE EXPERT EXECUTIVE, (New York: John Wiley & Sons, 1988), 57.

4. The expert system must be open-ended; that is, as the world changes, it must be possible to add new rules, new methods, and new ways of assimilating and dealing with data.

Expert systems are still generally thought of as specialized systems, using special computer hardware and special programming languages such as LISP and PROLOG. However, simple expert systems are appearing on standard-sized personal computers using expert system "shells" - software frameworks for developing specific expert system applications[1].

EXPERT SYSTEM ARCHITECTURE

The architecture structure of expert systems is somewhat reminiscent of human cognitive structures and processes[2]. Just as there is no unique set of traits that define a human expert, not every expert system has the same architecture. However, certain generic attributes appear in most systems. Though a variety of terminology is used, there are generally three components of expert systems as seen in Figure 1. First, there is the KNOWLEDGE BASE which consists of the set of facts and heuristics, or "rules of thumb", about the particular domain. It is comparable to the long-term memory of the expert. The second element, the method of reasoning, is usually referred to as the INFERENCE ENGINE. The inference engine is the control structure that allows various hypotheses to be generated and

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[1]Edward Yourdon, MODERN STRUCTURED ANALYSIS, (New Jersey: Yourdon Press, 1989), 33.

[2]Larry Bielawski and Robert Lewand, EXPERT SYSTEMS DEVELOPMENT: BUILDING PC-BASED APPLICATIONS, (Reading: QED Information Sciences, 1988), 23.

tested. Finally, some type of dialogue structure or USER INTERFACE is included which allows the user to interact with the expert system and includes such aspects as a method of information acquisition, natural language interface and an explanatory interface[1].

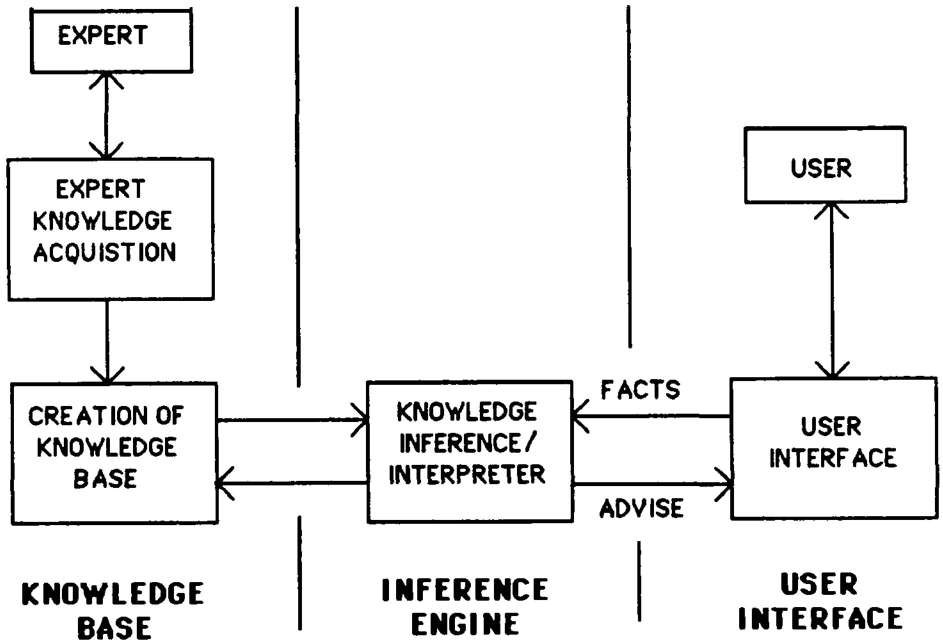

FIGURE 1: Expert System Architecture and Components
(Adapted from Hunt, 1986)

KNOWLEDGE BASE

Performance of the expert system is primarily a function of the size and quality of the knowledge base that it possesses[2]. A knowledge base is the information portion of the expert system

[1]Liebowitz, 4.
[2]Hunt, 26.

which normally contains both facts and rules. The first step in the creation of the knowledge base is to acquire the knowledge.

Usually two people are involved in the knowledge acquisition process: the expert and the knowledge engineer. An expert's power or expertise is generally derived from extensive domain specific knowledge such as, common facts, which consist of widely shared knowledge that is accepted by the professional and other accepted sources of data, and heuristics, or knowledge based upon good judgment and common practice or rules of thumb[1].

Experts rarely have the self-awareness to recognize the diverse extent and interaction of their knowledge[2]. Knowledge engineers, who are generally programmers or engineering analysts with the ability to transform knowledge from an expert into programming code, are needed to develop the knowledge acquisition process, to create reasoning programs to utilize the knowledge and to assure the logical collection of "expert" knowledge.

Knowledge representation depends heavily on logic to organize the knowledge base. It is a difficult task because of the complex intellectual relationships that must be anticipated and accounted for but are not always explicitly stated. The knowledge stored should be structured in a format which facilitates the system's reasoning. The approaches that AI developers have invented for representing knowledge in a knowledge system include array structures, semantic networks, property hierarchies, various list structures and predicate

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[1]David W. Rolston, ARTIFICIAL INTELLIGENCE & EXPERT SYSTEMS, (New York: McGraw-Hill, 1988) 9.

[2]Hunt, 26

calculus set[1]. Three common methods of representation are facts, rules, and frames.

Facts are pieces of information that can be used by expert systems. They are generally statements or conditions concerning the world and as such they are mostly transient and subject to change[2]. For example:

The real estate market is good.

The sky is blue.

Human experts can often make decisions based on incomplete, imprecise or uncertain information. Similarly, facts may sometimes be uncertain or inexact. In the statement above, we may only be 70 percent sure that the real estate market is good at a particular point in time. One way of expressing uncertainty is to state it in terms of one's confidence that a fact or rule is true. To represent confidence in a fact, a confidence or certainty factor (CF) is used[3]. In order for an expert system to get reliable information, the knowledge base must account for changes over time and uncertainty factors. Known facts guide the reasoning of an expert system since they determine which rules are currently applicable. The quality of the reasoning process is greatly affected by whether all the relevant facts are available to the system.

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[1]Clyde W. Holsapple and Andrew B. Whinston, BUSINESS EXPERT SYSTEMS,(New York: Richard D. Irwin, 1897), 37.

[2]Kamran Parsaye and Mark Chignell, EXPERT SYSTEMS FOR EXPERTS, (New York: John Wiley & Sons, 1988), 41.

[3]Bielawski, 36.

Facts by themselves cannot be used for reasoning. Facts relate together with rules to reason and derive new facts. A rule is a statement which normally contains a condition and an action. Rules were championed as a means of representing knowledge in a form that could be used for inference[1]. Most rules can be expressed in the general form:

IF premise

THEN conclusion;

An example is:

IF sky-color IS blue THEN raining is FALSE.

Facts and rules are important knowledge structures, but they do not provide easily accessible knowledge. A frame is a technique which accomplishes this task. It does this by assembling objects, attributes, and values into special structures called frames. This representation permits the hierarchical information about object relationships to be stored in the knowledge base[2]. For example consider the vehicle frame representation in figure 2.

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[1]Parsaye and Chignell, 45.

[2]Carl Townsend and Dennis Fuecht, DESIGNING AND PROGRAMMING PERSONAL EXPERT SYSTEMS, (New York: Tab Books, Inc., 1986), 56.

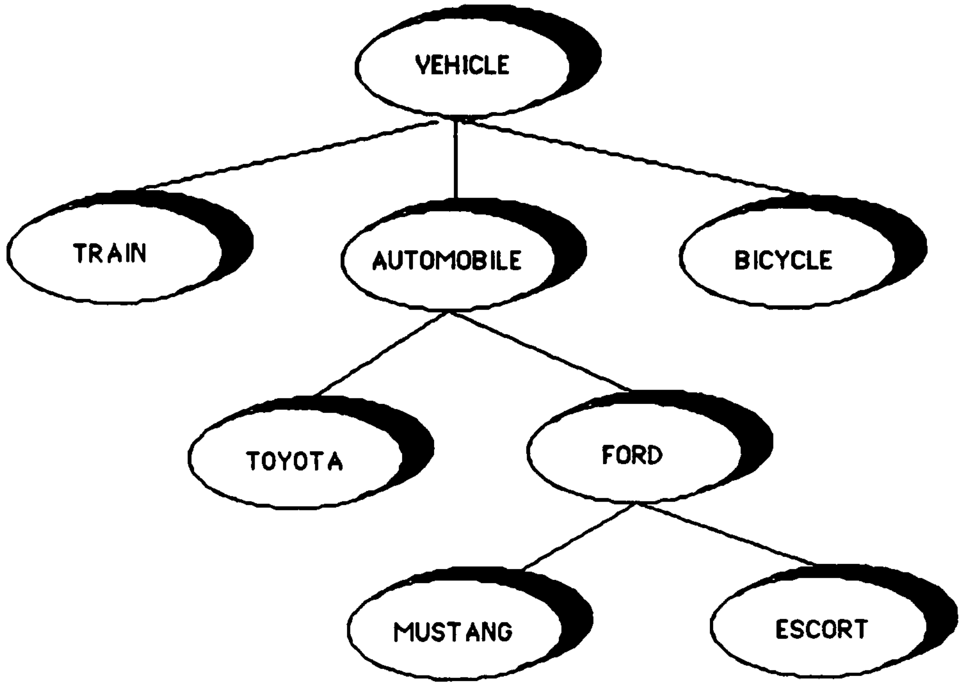

FIGURE 2: Vehicle Frame Representation
(Adapted from Parsaye, et.al., 1988)

A frame contains related bits of information about the subject of the frame; for example, vehicle size, options, and engine. Lower level frames automatically inherent the attributes from the parent slots, but may have additional, unique attributes. This type of representation is often called "object-oriented" because each frame represents an object type.

Frame representation is advantageous if the hierarchical relationship is relatively static and there are few exceptions to the relationships.

INFERENCE ENGINE

As indicated an expert system typically includes:

FACTS, which are elementary pieces of knowledge,

FRAMES, used to organize knowledge, and

RULES, which relate facts and frames.

Collectively, these facts, rules and frames are referred to as the knowledge the expert system possesses. To arrive at conclusions, the expert system relates pieces of knowledge by performing inference or deduction. The part of an expert system that performs inference is called an inference engine[1].

The concept of inference is based on simple logic. If we have a rule that states: IF sky-color IS blue THEN raining IS false,
and we have the fact: sky-color IS blue,
we can infer the fact: raining IS false,
by applying the rule to the fact. The inference engine then places the new knowledge in the knowledge base as a fact. Any subsequent rule determinations could use this fact, such as: IF raining IS false THEN air pressure IS high.

The method in which inferences are drawn is known as either FORWARD CHAINING or BACKWARD CHAINING. Forward chaining is a bottom-up reasoning process that begins with known conditions or facts and makes inferences to reach a goal[2]. It focuses on the premise rather than the conclusions of the rules. The inference engine systemically and repeatedly cycles through the rules until one is found whose premise matches a fact. This rule is then proved or

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[1]Parsaye and Chignell, 57.
[2]Rolston, 10.

"fired" and the conclusion is added to the database. Forward chaining is sometimes referred to as a "brute force" method of reasoning.

In backward chaining inference, the decision process is reversed. A top-down reasoning process, the system accepts a goal or hypothesis and tries to determine which other goals need to be proven in order to prove the initial goal[1]. If these goals are not immediately available, they serve as new hypotheses that require further inference and so on. This type of reasoning is referred to as "backward chaining" because one is reasoning backward from the hypotheses to the data.

A classic example of both forward and backward chaining is the medical diagnosis process. The doctor examines a few of the patient's symptoms and places him/her in a particular diagnostic category, such as orthopedic injury or respiratory ailment. This is forward chaining used to prioritize goals. Secondly, the doctor chooses from the categories, respiratory ailment, for example, and examines the listed symptoms to see if they correspond to the patient's, a backward chaining inference process.

The most versatile system can use both techniques, but many expert systems utilize only one. It is not possible, or desirable, to say that forward chaining is better than backward chaining or vice versa. Indeed, many problems can be solved by either method or a combination of both, depending on how the system's rules are structured[2].

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[1]Parsaye and Chignell, 66.

[2]Donald T. Hawkins, "Artificial Intelligence and Expert Systems for Information Professionals: Basic AI Terminology," ON-LINE, Sep. 1987: 91.

The specific nature of the problem may determine which problem-solving method is best. Backward chaining rules are useful for diagnostic and deterministic decision processes; i.e. situations with specified sets of outcomes. Forward chaining rules are most appropriate for monitoring processes, where the system has to intercept a set of incoming facts. The "firing" of forward chaining rules often triggers a series of backward chaining inferences[1].

Some experts further classify the inference engine into consisting of two components. The first is the knowledge base management system which "manages" the knowledge base by automatically organizing, controlling, propagating and updating stored knowledge. It initiates searches for knowledge relevant to the line of reasoning upon which the inference subsystem, the second component, is working. The symbolic inference subsystem provides the process, backward or forwarding chaining, by which lines of reasoning are formed[2].

USER INTERFACE

While the knowledge base and the inference engine are the basis for the experts system's reasoning, the user interface may also influence whether the expert system's advise will be accepted and put to use[3].

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[1]Laurence E. Huber and Rahn Carlson Huber, "Cracking the Researcher's Monopoly on Expert System Expertise," INDUSTRIAL ENGINEERING, Jan. 1988: 88.

[2]Hunt, 28.

[3]Parsaye and Chignell, 33.

If the system is difficult for the intended users to operate, chances are that they will fall back on their old ways of solving the problem and not use the system at all. They may simply not be willing to expend the intellectual effort required to use a new technology. Knowing the audience is an important first step in designing an interface. Developers cannot create an appropriate interface until they identify the range of experience of the users[1].

Besides the ease of use, another aspect of an effective user interface is the facility of explanation of the system's reasoning. Although studies reveal that people tend to have a lot of faith in information generated by a computer, no serious user of an expert system will accept its recommendations if the system is unable to explain how it reached it conclusions. This is especially true if the advise of the system differs from what the user would have guessed. Because a solution from a rule-based system is achieved by a series of fired rules, the system can provide an explanation of its reasoning by showing what the rule was and why it was fired[2].

Another request that a user may make of the system is for the system to explain why it is asking the user a certain question. The user may feel, for example, that a certain question is irrelevant to the problem at hand and may be curious as to why the expert system even raises it. A well designed user interface can accommodate this type of request for additional information.

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[1]Bielawski, 194.

[2]Robert G. Bowerman and David E. Glover, PUTTING SYSTEMS INTO PRACTICE, (New York: Van Nostrand Reinhold, 1988), 23.

EXPERT SYSTEM OPPORTUNITIES

The emerging expert systems software technology can provide a range of benefits in various applications if properly employed.

CAPTURE KNOWLEDGE: The capture of a specialist's knowledge is the primary justification for expert system implementation. This benefit is the result of condensing the specific, domain-dependent problem-solving knowledge of an expert or group of experts into a computerized system. The system can then be queried for knowledge facts like a database system. It can be asked to make inferences based on the knowledge in the knowledge base and to produce justification of the "reasoning" strategies and decision paths used in reaching a conclusion, as mentioned in an earlier section.

CODIFY EXPERTISE: Additional rationale for expert system implementation is its' ability to codify expertise. This codification helps formalize the expert's knowledge making it available to a wider audience. Knowledge codification also contributes to the repeatability and the reliability of the judgements of one expert or to produce consistency among a group of experts[1].

TIME SAVINGS: Frequently experts spend a large portion of their time doing only moderately specialized, routine work. Codification can produce stand-alone or assistant capacity systems which free up more of the experts' time[2]. As a consequence the experts can spend the majority of their time on creative endeavors in

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[1]Robert A. Edmunds, THE PRENTICE HALL GUIDE TO EXPERT SYSTEMS, (New Jersey: Englewood Cliffs, 1988), 21.

[2]Edmunds, 22.

problem solving and allow routine decisions to be delegated to the machine.

MAINTENANCE AND UPDATE SAVINGS: Another goal of expert system implementation is the savings of maintenance and updating the knowledge base. The clear distinction of facts, heuristics and deduction knowledge in knowledge-based systems reduces maintenance and update costs because the effects of changes are restricted to particular knowledge chunks in the knowledge base[1].

AVAILABILITY: There are numerous other advantages of expert system use, but two stand out because of the economics involved. First, many simultaneous users can be accommodated by an expert system. Consultation with a human expert, in contrast, is usually one-to-one or, at most, in small groups. Second, because the knowledge base is contained in the system, the expertise remains available even when the human expert has departed[2].

EXPERT SYSTEM LIMITATIONS

Unfortunately, expert systems have several restrictions. These limitations need to be noted before a determination is made on whether or not an expert system is the advisable solution to an individual or company's decision-making problem.

CAPTURE OF LIMITED TYPES OF KNOWLEDGE: Expert systems function on the domain of extracted, cognitive, logical thinking processes. They are generally not adept at managing highly

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[1]Bowerman, 13.

[2]Dwight B. Davis, "Artificial Intelligence Goes to Work," HIGH TECHNOLOGY, Apr. 1987: 18.

sophisticated sensory input or mechanical motor output[1]. Current expert systems cannot tackle broad, multiple-direction problem spaces. In addition, only knowledge that can be derived from the expert and implanted into the system can be used. The actual intelligence cannot be extracted. "Today's expert systems fall well short on dimensions requiring general intelligent behavior. They are more akin to idiot savants than to real human experts," say knowledge-engineering experts[2].

The very type of knowledge used by human experts can also be a limitation. To a great degree, the flexibility of human problem solving is based on a broad background of ill-defined common sense knowledge. Common sense is found to be important when performing cognitive operations in either familiar or unfamiliar situations and tends to play a greater role in the familiar areas, the very field of the expert's specialty. This type of knowledge is difficult to codify even if its influences are understood. Common sense knowledge and broad ranging conceptual information are not available in the typical expert systems of today.

LIMITED ERROR AND RECOVERY CAPABILITIES: Limited error exception and recovery is another difficulty in expert systems. Expert systems typically do not respond well to situations outside their range of expertise. Performance can degrade and result in a major, project-halting catch.

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[1]Bowerman, 17.

[2]F. Hayes-Roth and D.A. Waterman, BUILDING EXPERT SYSTEMS, (Reading: Addison-Wesley, 1983), 55.

TIME-CONSUMING TASK: Additional disadvantages have been discovered by companies utilizing expert system technology. Expert systems technology can be expensive, especially when extracting knowledge from experts is time consuming. Some thought processes have become second nature and, as a result, require a tremendous amount of time and energy to extract and codify. Knowledge development can sometimes take up to a year or more[1].

RELIANCE ON EXPERTS: Reliance on expert opinion has inherent limitations as well. One is "when you emulate experts, you also emulate their faults." Lacking common sense, an expert will not do well in unanticipated circumstances[2]. Similarly, some experts lie because they feel threatened, see change coming, and want to protect themselves and their opinions. There is the additional difficulty of conflicting advise among experts, the tendency of experts to display tunnel vision and the experts' limits in depth and breath of skills[3].

As noted, experts in knowledge-based systems believe expert systems are capable of performing within a specific, logical-oriented realm of expertise. The deeper values of human consciousness, interwoven as they are into the phenomenon and expressions of human intelligence, however, are beyond the range of anything currently available in AI[4].

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[1]Huber and Huber, 59.

[2]Andrew Kupfer, "Now, Live Experts on Floppy Disks," FORTUNE, Oct. 1987: 78.

[3]Randall Davis, "Expert Systems: How Far Can They Go?" AI MAGAZINE, Summer 1989: 66.

[4]Bowerman, 18.

PROBLEM AND DOMAIN IDENTIFICATION

Given the limitations of current technology in expert systems, the first critical aspect of application development is choosing a problem of appropriate degree of difficulty. One expert states the three important rules in developing expert systems is "pick the right problem, pick the right problem, and pick the right problem[1]."

Before development of an expert system begins two determinations must be made. A problem must be selected and its domain clearly established. The need for a definite establishment of a domain is due to the nature of expert systems. In general, the knowledge of a expert is useful only for a particular type of problem. Once the nature of the problem to be solved crosses the boundaries of the domain, the expert system becomes ineffective[2]. As one expert states, "the task must have a domain to avoid the combinatorial explosion of the alternatives[3]."

A variety of vague economic and situation dependent criteria have been written about assessing the viability of programming an expert system for a particular domain or problem. However, the following, well-established rules are generally provided for guidance[4]:

- The problem should have a well-bounded domain, neither too complex or too simple. Selecting too large a problem or one with few test cases could lead to disastrous results. Picking too trivial a

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[1]Liebowitz, 3.
[2]Huber and Huber, 59.
[3]Liebowitz, 4.
[4]Edith Myers, Expert Systems: Not for Everyone," DATAMATION, May 1986: 28.

problem will leave managers and users unimpressed and will probably not be worth the effort for development.

- The domain must be decision-oriented as opposed to creative in nature. The decision maker must have some specialized expertise to be effective in the task.

- The problem requires the development of multiple hypothesis or alternatives and the need to explore them rapidly. The decision should be goal-oriented, with the expert decision maker deciding among concrete outcomes; e.g. Fault A, Fault B, or Fault C.

- The problem requires the use of experience rather than common sense as the key to the solution.

- The number of outcomes should be discrete and fairly small. Continuous goals, such as "invest 20% in stock, 11% in real estate, ect.," are difficult to model. Similarly, the amount of programming increases with the number of goals in the domain.

- The decisions being modelled should be made fairly often and require a few minutes to a few hours for a human to make. A prime example of short-duration decision making is troubleshooting.

- The decision is better made using expert knowledge rather than non-expert knowledge.

Guidelines for expert systems use include solving problems where people have experience that cannot be modeled quantitatively. Expert systems are not for problems that are unsolvable or problems that can be solved by mathematical models. Some opportunities for use of expert systems lie in areas where there are an insufficient number of experts to provide needed knowledge, where there is inconsistent job performance and poor quality of work, and where

there is a predominance of knowledge intensive as opposed to clerical tasks[1]. In these areas, expert systems can incorporate an expert's knowledge, provide multiple access to the knowledge, and ensure consistent high quality expertise is available as needed.

CURRENT EXPERT SYSTEM APPLICATIONS

Based upon the opportunities and limitations presented, expert systems should be viewed as offering new ways of doing old things: to solve problems that thwart data processors, to preserve perishable expertise, to distribute expertise, to fuse multiple sources of knowledge, to convert knowledge into a competitive edge and to alter business common sense and perspective.

Today, users of expert system applications are doing just these things. In figure 3, the generic categories of expert systems applications are presented. Other experts include additional categories such as fault isolation, scheduling, analysis, maintenance, configuration, and targeting resource allocation[2]. These types of problem categories may be found in such areas as agriculture, chemistry, computer systems, electronics, engineering, geology, information management, law, manufacturing, mathematics, medicine, meteorology, military science, physics, process control, or space technology areas[3]. In 1987, companies spent an estimated $250 million on software for developing expert systems. This number is

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[1]Myers, 29.

[2]Liebowitz, 6.

[3]D.A. Waterman, A Guide to Expert Systems, (Reading: Addison-Wesley, 1986), 40.

projected to increase to $700 million for expert systems development in 1990[1].

CATEGORY	PROBLEM ADDRESSED
Interpretation	Inferring sitation descriptions from sensor data
Prediction	Inferring likely consequences of given situations
Diagnosis	Inferring system malfunctions from observables
Design	Configuring objects under constraints
Planning	Designing plans of action
Monitoring	Comparing observations to anticipated outcomes
Debugging	Prescribing remedies for malfunctions
Repair	Executing a plan to administer a prescribed remedy
Instruction	Diagnosing and rectifying student performance
Control	Controlling overall system behaviors

FIGURE 3: Generic Categories of Expert Systems
(Adapted from Hayes-Roth, et. al., 1983)

Examples of some of the current, successful applications in these areas follow.

• The greatest use of expert systems has been in China where knowledge engineers are capturing the knowledge of rural, herbal doctors, a dying profession that goes back millennia, and distributing this expertise throughout the country with expert systems[2].

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[1]Kupfer, 69.
[2]Kupfer, 70.

• Digital Equipment Corporation (DEC) uses an expert system called XCON (eXpert CONfigurer) to help configure its complex minicomputer systems. Each system must be specifically designed to meet an individual customer's requirements. When this task was performed by highly-trained engineers, few of the systems produced were completely correct. Often something a simple as an improper cable costing a few dollars would delay the implementation of a $100,000 system. Today, most systems go out correct. By some estimates DEC is saving about $25 million a year using expert system technology[1].

• Several large insurance companies are using expert systems software to help handle their business. A system, called The Underwriter Advisor, is being used to act as a consultant to the underwriter. As would be the case with a human consultant, the underwriter is still free to accept or reject the advise of the expert system[2].

• The company, Combustion Engineering, utilizes expert systems to rapidly redesign the parts it uses to manufacture coal-burning boilers for power utilities. The company estimates that the system compresses 1000 hours of engineering time into about 100 hours; productivity gains of ten to one[3].

• At American Express, expert systems decide if someone making a purchase is a fraud or a deadbeat. It allows less

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[1]Edmunds, 4.
[2]Linda Runyan, "Hot Technologies for 1989," DATAMATION, Jan. 1989: 18.
[3]Runyan, 18.

experienced workers to arrive at credit judgements that are as sound as an experts[1].

• The United States Department of Defense (DOD) has defined AI as one of the one most critical technologies to pursue in the remainder of this century. Through the Defense Advance Projects Research Agency, the DOD is channelling hundreds of millions of dollars into universities and private industry to create next generation machines and software[2]. Some examples of where the military is utilizing expert systems are in the Navy, where they select the proper types of acoustic buoys to throw into the water to locate enemy submarines, or in the Air Force, where fighter jets are supplied with systems to identify aircraft[3].

• Certain hospitals within the United States are using expert systems to diagnose and prescribe cures for specific diseases. The best known system is MYCIN, which provides advise to physicians in treating patients with bacterial infections[4]. Another expert system program called PUFF, is diagnosing certain lung diseases with almost 90 percent accuracy. The system compares various measures of lung functions against profiles drawn from case histories of victims with lung disease[5].

Expert systems have shown vast commercial promise in the past few years. In fact, expert systems may eclipse all other areas of AI research and development activities. As illustrated, many

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[1]Kupfer, 69.
[2]Edmunds, 6.
[3]Kupfer, 70.
[4]Hawkins, 93.
[5]Edmunds, 12.

successful expert systems have already been placed into production. However, there is general agreement that these early systems have barely scratched the surface of what is almost surely destined to become a common place technology by the end of the century.

RESEARCH QUESTION

The question appears to be whether or not expert systems can truly augment or replace human expertise as we know it. Some examples have been provided which illustrate where expert systems are currently working with apparent success. In these applications, expert systems have augmented the work of an expert. Among these applications there appear to be several common factors. Essentially, existing expert system applications have replaced or augmented human experts who used similar thinking processes in their decision making, made similar types of decisions, and performed similar types of functions.

One way to determine if a particular type of expertise can be supported by an expert system would be to determine if the characteristics of their decision making are equitable with the decision making elements of existing expert systems.

Although, it appears as if little or no research has been conducted addressing this paper's specific concern - the augmentation of U.S. Army warrant officer expertise - it has been demonstrated that human expertise can be supplemented in certain areas and under certain conditions. Whether or not these conditions exist within the U.S. Army warrant officer system still remains undetermined. Warrant officers are the Army's experts and fit the term "expert" is

every sense of the word. They have extensive training and experience in a particular field that allows them to make quick and proficient decisions or recommendations. Therefore, it would follow, that the expertise of a warrant officer is not unlike that of others experts, to include those that are supported by expert system applications.

This paper will attempt to determine if this is indeed the case, by answering the following research question:

Can automated expert systems be effectively and efficiently used to augment the diminishing knowledge base of personnel, intelligence, and supply warrant officers in order to keep valuable and needed expertise within the U.S. Army's organization?

This research question will be answered by determining whether or not:

1) The type of cognitive decision processes used by these particular warrant officers in their daily decision-making is suitable for use in expert systems,

2) The type and characteristics of decisions made by warrant officers are equitable to the characteristics of decisions that can be proposed by expert systems, and

3) The daily functions performed by warrant officers fall within the current categories of proven working and effective applications of expert systems.

CHAPTER THREE: ANALYSIS

Based upon the available secondary research in successful expert system applications outlined in Chapter Two, it is possible to create a model which profiles appropriate expert system application problem selection criteria. The research indicated that the appropriate expert system problem is primarily a function of the type of thinking processes used *in decision*-making, the characteristics of the decision, and the functions where the decision-making occurs. This functional relationship can be seen in a mathematical view of the model in Figure 4.

$$C = f(A_1, A_2, A_3)$$

Where,

C = Expert System Selection Criteria
A_1 = Type of Thinking Processes Used
A_2 = Characteristics of Decisions
A_3 = Functions Performed in Decision Making

Figure 4: Mathematical Model: Expert System Application Criteria

In the decision-making thinking process, known facts and the use of experience or information available through printed material, are best suited for expert system applications. The use of common sense in decision making is not easy to codify. Additionally, mathematical models are not suitable for expert systems. The types of decisions that are easily generated by expert systems are generally routine, non-creative, and require, on the average, 1 minute to 3 hours to make. Expert systems work well in situations that are decision-oriented, utilize an expert's knowledge in the decision solution and perform a variety of functions listed in Figure 3, Chapter 2. These specific values, determined by this researcher's analysis of available expert system information and research, can been seen in Appendix A.

In order to answer the research question: whether or not automated expert systems can be effectively and efficiently used to augment the diminishing knowledge base of personnel, intelligence, and supply warrant officers in order to keep valuable and needed expertise within the U.S. Army's organization, a survey was created and distributed to supply, intelligence, and supply warrant officers in order to provide data on the variables indicated earlier. The variables were measured and then applied to the Expert System Application Criteria Model (Appendix A). The methodology of the process follows.

RESEARCH DESIGN

In this paper, the independent variable is the warrant officer's branch speciality: personnel, intelligence, or supply. The dependent variables are the thinking processes utilized, the decision characteristics, and the functions performed. Since the research question can be answered by simply measuring these dependent variables, and not by manipulating them, an Ex Post Facto research design was selected.

Specifically, a survey design was chosen for three reasons. First, the survey design allowed this researcher to study and describe three somewhat large populations fairly quickly. With the time constraints of this project it was essential to have a quick method of data collection. Second, survey costs are relatively low compared to other designs, solving another problem constraint of the project. Finally, surveys have been used successfully to describe population characteristics which is the primary purpose of this paper[1].

MEASUREMENT TOOLS

The design of this project's questionnaire (see Appendix B) was accomplished with the following factors in mind:

1) Effective measurement,
2) Data validity, and
3) Physical format.

[1]Duane Davis and Robert Cosenza, BUSINESS RESEARCH FOR DECISION MAKING, (Boston: PWS-Kent Publishing, 1988), 111.

In order to measure the dependent variables, elements in the Expert System Application Criteria Model were incorporated into the questionnaire. The elements of the model and corresponding questionnaire measurements are depicted in Appendix C. In most cases, ordinal measurements, in the form of Likert Scales, which provide information about the relative amount of some trait possessed by an object or individual, were used. Some nominal measurements were also designed into the questionnaire for classification usage.

In order to ensure data validity, multiple procedures were undertaken. An extensive search of the literature was conducted in the development of the descriptive model. As a result, during the survey design all elements of the model were included in order for each to be measured and to ensure *content* validity. Construct validity was added into the survey by including two different measurements which measure essentially the same concept or a measurement scale that could be differentiated from another scale measuring a different concept. This method of data validity was selected primarily because time and cost limitations did not allow for survey pre-testing. A listing of validity checks is provided in Appendix D.

The design of the physical format was developed essentially with the thought of receiving as many valid responses as quickly as possible. The size, therefore, was limited to one page, front and back. The questions were presented in increasing order of difficulty, so as to not frighten a respondent away. Likewise, personal data was the last section of information to complete. With the exception of the

personal data, all questions were closed-ended for ease in respondent answering and researcher coding and analysis.

A review of Appendix C indicates that a few questions were included in the survey that do not serve any useful measurement purpose. These were included into the survey in error as the researcher had originally thought to also measure conditions under which expert system use is beneficial, i.e. when an expert departs an area without an immediate replacement. After working with the Expert System Application Criteria Model it was determined that conditions where expert systems were helpful was irrelevant to problem selection. Retroactively, however, these irrelevant questions did serve a purpose. This survey was distributed to the warrant officers without an explanation of the research question it was attempting to answer. The subject was kept unknown due to the fact that the researcher thought the responses might to skewed in one direction or another because of the potential effect an expert system may, or may not, have on a warrant officer's perceived employment. The questions that served no measurement purpose helped broaden the types of questions asked and, therefore, hide the underlying meaning of the relevant questions.

SAMPLING PROCESS

An analysis of three populations was conducted for this research: personnel warrant officers, intelligence warrant officers, and supply warrant officers. The three populations were finite with 448, 144, and 302 units per population, respectively.

The sampling design used was systematic sampling. The Warrant Officers Branch of the U.S. Army Personnel Command provided complete listings of the three populations. Using natural ordering, a randomly selected start point, and the sampling ratio for the particular population, a sample selection of warrant officers was made.

Several factors were considered in determining the sample size, the most important of these was having confidence that the sample captures the true and precise population parameters. Additionally, past response rates in this type of project were considered in order to ensure a significant number of responses were available for analysis. A sample size of 30 percent of the population was selected with the exception of the intelligence population, which had a relatively small population to select from. A larger percentage of the population was selected in order to ensure a significant amount of responses were received for analysis. A summary of the sampling statistics is provided in Appendix E.

DATA ANALYSIS

As indicated at the beginning of this chapter, a descriptive, and somewhat theoretical model exists for determining if an application is suitable for expert system implementation. The basic premise of this paper's analysis methodology was to develop a profile of thinking processes, decision characteristics, and functions performed for each population, and then to compare these profiles to the Expert System Application Criteria Model. If the variables in the profile compare favorably with the model variables a determination can be made that

the decisions and decision-making processes utilized by that population are suitable for expert system application.

Data Statistics: Due to the descriptive nature of the research and the goal of describing the criteria of suitable expert system use, summary statistics were determined to be the most appropriate analytical method for this project.

Data provided by nominal measurement was used by determining the most frequent appearing response, or the Mode. Data provided through the use of ordinal measurement measured Central Tendency and Dispersion, by computing means, medians, modes, ranges, and standard deviations of each variable measured. The specific types of summary and tabulation statistics can be seen in the appendices where the primary data for each population is presented (Appendices F, G, or H).

Profile Development: The summarized statistics were then used to develop a profile of each populations' decision-making variables. Elements added to each profile were determined by:

1) Mode responses for Part I.

2) Responses of greater than 3 for Part II questions were defined as a positive response.

3) Responses of less than 3 for Part II questions were defined as a negative response.

4) Responses of 3 for Part II questions indicated irrelevancy and, therefore, were not added to the profile.

5) Responses of 2.5 or greater for Part III questions were defined as a positive response.

6) Responses of less than 2.5 for Part III questions were defined as functions that were not significantly utilized and, therefore, were not added to the profile.

The sample profiles of personnel, intelligence, and supply warrant officers populations are provided in Appendices I, J, and K, respectively.

Model Comparison: As a final step in the data analysis, each profile element and corresponding measurement was compared to the Expert System Application Criteria Model. The results of this comparison as well as all the analysis mentioned earlier is presented in the following section.

RESULTS

The Personnel Warrant Officer Profile: The profile of the personnel warrant officer was developed using a sample size of 67. The total number of responses was 79, however, 12 responses were thrown out because of the incompleteness of questionnaires and possible validity problems. As mentioned earlier when discussing validity checks, a response of one type of question indicated that a particular response should follow for another type of question (see Appendix D). Three responses were eliminated because of incompleteness while the rest were disregarded due to possible validity errors. Analysis of the remaining responses indicated that the thinking process, decision characteristics, and functions

performed and utilized by personnel warrant officers paralleled the model in all but three areas.

In determining the thinking process used, 76 percent of the respondents indicated that past experience was the primary factor used in making decisions. The second most frequent response, of which 19 percent of the respondents replied, was researching army regulations and manuals. Both of these methods are deemed appropriate when determining applicable expert system applications. A mere 4 percent of the respondents indicated common sense as the primary element used in decision making. The extent of experience used ranged from "almost never" to "almost always." The mean, median, and mode were 3.0 in all cases, proving essentially nothing one way or another. Logically, this response should have averaged above a 3.0 as determined by the large percentage of "experience" responses in the earlier question. This conflict could be explained by the somewhat confusing wording of the question. This problem will be discussed later in Chapter 4 under Possible Problem Areas. Ninety-four percent of the respondents indicated that common sense was used in their decision making from a range of "never" to "sometimes." This data supports the earlier response of only 4 percent who indicated that common sense was the primary factor in their decision making process. The mean response for use of mathematical models was 2.58 indicating that respondents used models less often than "sometimes." The final variable of the thinking process, the use of known facts, measured 21 percent of the responses. Seventy-five percent indicated that both facts and intuition were used in the process. Thus it can be concluded that in

the decision making thinking process, experience is used, common sense and mathematical models are not significantly used, and known facts are taken into consideration but only in conjunction with intuition or personal insight.

In determining the characteristics of decisions made by personnel warrants, 78 percent of the respondents indicated that most decisions take one minute to three hours to make with the majority of those responses (76 percent) being 1 to 59 minutes. Likewise, the mean responses to the regularity of the decision was a 4, or an "almost always" response. The mean responses to the creativity of decisions was 2.97. Here responses ranged from "always" to "never" with the most frequent response being "sometimes." Based upon these responses, most decisions made by personnel warrants can be said to be routine, take 1 minute to 3 hours to make, and are not creative in nature.

The applicability of functions performed was measured by determining the use of knowledge, whether or not functions were decision-oriented , and the generic types of functions. Ninety-one percent of the respondents indicated that their knowledge of an area was used in the performance of their work, with the mean response being 3.4. The mean response of work being decision-oriented was 4.0, with 96 percent indicating a "sometimes" to "always" response. Personnel warrants responded with a 2.5 or better mean responses in the following functions: diagnosis (2.66), debugging (2.88), instruction (2.67), analysis (2.58), scheduling (2.55), and fault isolation (2.70). Prediction and target resources allocation were not significant functions performed by personnel warrants.

Comparing the profile to the model, only one significant difference is apparent - the use of known facts. Facts were used in the thinking process but the degree to which they were used was undetermined. The comparison of the measured variables to the Expert System Application Criteria (ESAC) model is in Appendix L.

The Intelligence Warrant Officer Profile: The profile developed on the intelligence warrant officer differed in many respects from the personnel warrant officer profile. A sample size of 33 was analyzed. The total number of responses was 37, however, one was deemed invalid due to incompleteness and the remainder due to possible validity errors. Analysis of valid survey responses indicated that the thinking process, the decision characteristics and the functions performed differed from the ESAC model in several of the areas measured.

In determining the use of experience versus common sense in the thinking process, 61 percent responded that past experience was the primary factor used in decision making. However, like the personnel respondents, 70 percent indicated that the extent of experience used was only "sometimes." This response could again be the result of poor survey questioning. A mean response of 3.0 in this case was inconclusive. Only 39 percent of the respondents indicated that common sense was the primary factor used in decision making, with 88 percent responding that common sense was used with a frequency from "never" to "sometimes." The majority of the respondents indicated that mathematical models were "almost never" used in their decision making process. The mean response to this

question was 1.94. Only 12 percent indicated the use of known facts in the decision making process, while 79 percent indicated both facts and intuition were used. This is a repeat of the dilemma presented in the personnel warrants' result and is explained in greater depth in Chapter 4. Thus, it can be concluded that experience is used in the decision making thinking process, common sense and mathematical models are generally not used, and known facts are utilized along with intuition.

In determining the characteristics of decisions made by intelligence warrants, 30 percent indicated that decision making took less than 1 minute to make; 64 percent, 1-59 minutes; and 6 percent, 1 - 3 hours to make. None indicated that the process took greater than three hours. The mean response to the regularity or routine nature of the decisions was 3.61. *In this case*, the mode was a 3.0, or a "sometimes" response, while the median was a 4.0, or an "almost always" response. In this case, however, 91 percent indicated that this work was creative in nature, ranging from "sometimes" to "almost always". The mean response was 3.30. Based upon these responses, it can be surmised that most decisions made by intelligence warrants are routine, take 1 minute to 59 minutes to make, and are creative in nature.

In determining the types of functions performed, 91 percent of the respondents stated that they used the knowledge they have in the performance of their duties. The mean response was 3.30, indicating more often than "sometimes." The mean response of work being decision-oriented was 3.61, with 55 percent responding that their work was "almost always" decision-oriented. Intelligence

warrants responded with a 2.5 or better response in only one out of the eight functions measured. Sixty-one percent of the respondents answered that instruction was "always" one of the functions they performed. A summation of the intelligence warrant officer's profile is in Appendix J.

Comparing the profile to the ESAC model (Appendix L), it is apparent that the two do not closely correspond. The use of known facts is not determined and creativity is a characteristic of the decisions in the intelligence warrant officer's decision making process.

The Supply Warrant Officer Profile: The profile of the supply warrant officer was developed using a sample size of 50. The total number of responses was 52, however, 2 were eliminated due to incompleteness. Analysis of the variables indicated that the developed profile closely parallels the ESAC model.

In determining the decision making thinking process, 90 percent of the respondents answered that past experience was primarily used in decision making. Researching regulations and manuals received 4 percent, and the use of common sense rounded out the responses with 6 percent. The corresponding questions on the extent of experience and common sense use reinforced these responses. Ninety-four percent indicated that experience was used with responses ranging from "sometimes" to "always." The mean of these responses was 3.18 indicating more often than "sometimes." Again, 94 percent indicated that common sense was used from a frequency of "never" to "sometimes." Here the mean response was 2.80, indicating less often than "sometimes." The mean response to

the use of mathematical models was 2.72 indicating less often than "sometimes." Eighty-four percent indicated that models were used with the frequency of "never" to "sometimes." The determination of the use of facts, for the third time, indicated that 68 percent used both facts and intuition in the decision making process. Supply warrant officers did have the highest response (32 percent) of the three groups studied for the use of facts. Based on these results, the decision making thinking process does use experience, does not use common sense or mathematical models, and does use both intuition and known facts.

In determining the characteristics of decisions made by supply warrants, 70 percent of the respondents indicated that decisions took from 1 minute to 59 minutes to make. The remainder of the responses stated that decision making took less than 1 minute. One hundred percent of the respondents indicated that their work involves routine decision making with a frequency of "sometimes" to "always." The mean response was 4.08 indicating a more often than "sometimes" response. Likewise, creativity of decisions appeared insignificant with 82 percent of responses in the range of "never" to "sometimes." The mean response, 2.90, indicated that supply warrant officer work was creative in nature less often than "sometimes." Based upon these statistics, it can be concluded that decisions made by supply warrants take 1-59 minutes to make, are routine, and are not creative in nature.

In analyzing the functions performed by supply warrant officers, the use of knowledge in their work area had a mean response of 3.46, with 94 percent ranging their responses from

"sometimes" to "always." Within the same range, 100 percent of the respondents indicated their work was decision-oriented. The mean response was 3.82, the median and mode both equalled 4.0 meaning an "almost always" response. Supply warrant officers responded with a 2.5 or better mean in the following functions: debugging (2.58), instruction (2.88), analysis (2.62), scheduling (2.62), and fault isolation (2.54). The data measurements for each variable of the supply warrant officer profile is in Appendix K.

Comparing the supply warrant officer profile with the model (Appendix L) shows the closeness of the variables. Only one element is different: use of known facts.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

POSSIBLE PROBLEM AREAS:

Prior to presenting the conclusions and recommendations of this paper, it is necessary to present and discuss some of the areas I identified as possible problems. These problems have been identified throughout the research project's life cycle and, usually, at a point too late to rectify without added delay, cost, and possible incompletion of the project. As a result, these errors are inherent in the project, may have an affect on the resultant data, and need to be presented. The majority of these errors are a result of inexperience. The errors, some of which have been alluded to in the previous chapter, are within the survey design. Please refer to Appendix B for the survey design.

Problem Area One:

The question asked in Part I, Question 1 of the survey attempted to determine the one element that had the greatest impact in the decision making thinking process. Because of this, the question

should have been designed using ordinal measurement in the form of rank order. Although I believe most respondents answered the question as intended, several added an additional response, such as "All of the Above", making the surveys invalid.

Problem Area Two:

Likewise, question 3, Part I, should have been rank ordered using some type of ordinal measurement. In this question, the opposite of Problem One occurred. Because a selection of "A Combination of Both" was included and the majority of the respondents correctly selected this response, I was unable to measure which element - Known Facts or Intuition - had the greater impact on the decision making thinking process. Without this measurement, I was unable to measure the variable against the model.

Problem Area Three:

Because of the wording in statements 2, 5, and 10 of Part II, the validity checks built into the system were somewhat insufficient. For example, statement 2 is: "I make decisions based solely on past experiences." The word "solely" indicates that no factor other than experience is involved in decision making. This was not the intention of the statement. The statement was to have been used as a validity check with Question 1 of Part One. If a response in question one had been "experience," then the response to statement 2 should have ranged from "sometimes" to "always." The term "solely" disabled this validity check from effectively happening. Again, I believe many respondents answered the question as I had intended. Several,

however, answered totally opposite as would have been supposed and a few even made written comments. Because of this, several surveys had to be disregarded in the analysis.

Allowances for these errors have been made as the situation permitted. Surveys returned with additional responses or without questions answered were not included in the statistical summary process. Likewise, questions that did not meet the validity checks, as inadequate as they were, were eliminated. Other than these two precautions, the following conclusions and recommendations were based upon the data provided by the survey. Any decisions made based upon this research project should be made with the realization of possible errors and faulty analysis.

CONCLUSIONS

In the area of personnel warrant officer expertise, the variables measured had a 90 percent correspondence with the ESAC model. That is, out of the ten elements of the model, the profile developed by the analysis matches the model in all areas with the exception of one: the use of known facts. Known facts are used but the extent of use as opposed to intuition is undetermined. Additionally, within the element describing the types of functions, the profile depicts six areas in which the type of work performed by personnel warrant officers are already successfully performed by expert system applications. Because of this high correspondence, I believe the expertise of personnel warrant officers is a prime candidate for an expert system application. However, because of the one element deviation, I would

recommend further research to clarify the use of known facts before resources are devoted to a personnel warrant officer application.

In the area of intelligence warrant officers, a greater deviation existed than for that of warrants in personnel. The variables measured only had an 80 percent correspondence with the ESAC model. Out of the ten elements of the model, there was a deviation in the use of known facts in the decision making thinking process and in the creativity of the decisions made. Additionally, the profile only depicts one functional area (Instruction) out of eight where intelligence experts are currently working. Although this model indicates that only one of the functions presented is necessary for appropriate expert system use, I believe it is essential to know what percentage of an intelligence warrant officer's time is spent performing this function. Taking all factors into consideration, I believe the work an intelligence warrant officer does cannot be augmented by an expert system and, therefore, recommend some other viable augmentation be selected and researched.

The same conclusion can be drawn for supply warrant officers as was drawn for the personnel warrants. A 90 percent correspondence between the profile and the model exists, with the only variation being the use of known facts in the decision making process. In the area of the functions performed, the profile presents five areas in which supply warrant officer work is similar to work currently performed by successful expert system applications. The work performed by supply warrants is a prime candidate for an expert system application, once further research has been conducted

which proves the significant use of known facts in the decision making process.

A final conclusion that can be made is that not all of the Army's expertise is alike and, therefore, no blanket conclusions can be made concerning the viability of expert systems to augment warrant officer expertise. Each area of expertise must be analyzed separate from the rest in order to make valid conclusions.

ADDITIONAL RECOMMENDATIONS

Besides the recommendation for additional research indicated in the conclusions, it is important to note that further research would be necessary before implementation. If a positive determination has been made concerning the use of expert systems to augment personnel and supply warrant officer expertise, further research is needed into the most effective, productive and nondisruptive methods of implementation. Like most organizations, the United States Army has limited resources and must manage these effectively and efficiently. In addition, care must be taken in the implementation of computer systems which may affect an individual's employment.

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EXPERT SYSTEM
APPLICATION CRITERIA MODEL
(ESAC Model)

Application Criteria = **Thinking Process**
+ **Decision Characteristics**
+ **Viable Functions**

Thinking Process = [Past Experience |
Knowledge from Printed
Material]
+ Known Facts
+ No Use of Common Sense
+ No Use of Mathematical Models

Decision Characteristics = Requires 1 min. - 3 hrs to solve
+ Routine Decision-Making
+ Not Creative

Viable Functions = Use of Knowledge
+ Decision-Oriented
+ [Fault Isolation | Debugging |
Scheduling | Prediction |
Targeting Resource Allocation |
Diagnosis | Instruction |
Analysis]

APPENDIX A

QUESTIONNAIRE: **Warrant Officers' Decision-Making**

Note: If you are currently in a branch immaterial position, please respond to questions using your last specialty assignment.

PART I: Please check the one, most appropriate answer concerning your daily work decisions:

1. Most of the decisions I make are a result of my:
   a. _____ Common sense.
   b. _____ Experience in my field.
   c. _____ Researching ARs and other manuals.
   d. _____ None of the above

2. Most of my decisions take:
   a. _____ Less than 1 minute to make.
   b. _____ 1 - 59 minutes to make.
   c. _____ 1 - 3 hours to make.
   d. _____ More than 3 hours to make.

3. I make most of my decisions using:
   a. _____ Known facts.
   b. _____ Intuition (i.e. personal insight).
   c. _____ Combination of both.
   d. _____ None of the above.

PART II: Please respond to the following statements by circling the appropriate number where:
1 = Never, 2 = Almost Never, 3 = Sometimes, 4 = Almost Always, and 5 = Always.

	Never	Almost Never	Some-times	Almost Always	Always
1. My work involves routine decision-making.	1	2	3	4	5
2. I make decisions based solely on past experiences.	1	2	3	4	5
3. My work is decision-oriented.	1	2	3	4	5
4. There is not enough time in the day for me to complete my work.	1	2	3	4	5
5. I make decisions based solely on common sense.	1	2	3	4	5
6. My work is creative in nature.	1	2	3	4	5
7. In my opinion, there is a difference in knowledge/experience between warrant officers of equal rank.	1	2	3	4	5
8. There is usually overlap time between incoming and outgoing warrant officers.	1	2	3	4	5

Please continue on backside.

II. Continued:

	Never	Almost Never	Some-times	Almost Always	Always
9. I use mathematical models in my decision making.	1	2	3	4	5
10. I make decisions based solely on knowledge I have concerning my area of expertise.	1	2	3	4	5

PART III: Please respond to the following comments regarding the types of functions you perform as a warrant officer where:

1 = Never
2 = Sometimes
3 = Always

	Never	Some-times	Always
1. I predict likely consequences of given situations.	1	2	3
2. I make diagnoses of malfunctions by observing people/ systems/situations.	1	2	3
3. I develop or prescribe solutions and remedies to problems.	1	2	3
4. I instruct or train individuals in my area of expertise.	1	2	3
5. I conduct analysis of data and information.	1	2	3
6. I am involved in the scheduling of resources. (i.e. people, events, equipment)	1	2	3
7. I attempt to discover faults in systems.	1	2	3
8. I am responsible for targeting resource allocation.	1	2	3

PART IV: Please fill in the blanks:

1. Age: _____
2. Branch/Specialty: ____________________
3. Years in Service: ________
4. Number of Years working in current field: _____
5. Number of Years as a warrant officer: _____

Thank you for taking the time to complete this questionnaire. Please return it as soon as possible using the pre-stamped, pre-addressed envelope.

SURVEY DESIGN -- Element Measurement

Number	Model Variable Element	Survey Question
1	Past Experience Use	Part I, #1 Part II, #2
2	Knowledge Available through Printed Materials	Part I, #1
3	No Use of Common Sense	Part I, #1 Part II, #5
4	No Mathematical Models	Part II, #9
5	Decision Time Requirements	Part I, #2
6	Routine Decision-Making	Part II, #1
7	Creativity of Decisions	Part II, #6
8	Decision-Oriented Work	Part II, #3
9	Use of Knowledge	Part II, #10
10	Functions Performed	Part III

APPENDIX C

SURVEY DESIGN -- Data Validity Checks

Convergent Validity Tests

Test Number	A Reponse Of:	Indicates	A Response Of:
1	A, Part I, #1		3-5, Part II, #5
2	B, Part I, #1		3-5, Part II, #2
3	C, Part I, #1		3-5, Part II, #10

Discriminant Validity Tests

Test Number	A Reponse Of:	Indicates	A Response Of:
1	3-5, Part II, #1		1-3, Part II, #6
2	1-3, Part II, #6		3-5, Part II, #1
3	3-5, Part II, #2		1-3, Part II, #5
4	1-3, Part II, #5		3-5, Part II, #2

SAMPLING PROCESS -- Statistics

	Population & Sampling Data:					Systematic Sampling Data:	
Population	Population Size	Sample Size	Percent of Population	Responses /Percent	Valid Responses	Sampling Ratio	Random Start Point
Personnel	448	135	30%	79/59%	67	3:1	First Name
Intelligence	144	72	50%	37/51%	33	2:1	Second Name
Supply	302	91	30%	52/57%	50	3:1	First Name
Total	894	298	33%	168/56%	150		

APPENDIX E

ANALYSIS -- Personnel Warrant Officer Sample Data Tabulation and Summary Statistics

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
1	Thinking Process	NML	Common Sense	3	4	4	Mode =
			Experience	51	81	76	Experi-
			Researching	13	100	19	ence
			None of above	0	100	0	
2	Time Factor	NML	< 1 min.	13	19	19	Mode =
			1-59 mins.	51	95	76	1-59mins
			1-3 hours	1	97	2	
			> 3 hours	2	100	3	
3	Use of Facts	NML	Known Facts	14	21	21	Mode =
			Intuition	3	25	4	Facts &
			Both	50	100	75	Intuition
			None	0	100	0	
4	Regularity	ORD	1	0	0	0	Mean = 4
			2	0	0	0	Median = 4
			3	17	25	25	Mode = 4
			4	33	75	50	Range = 3-5
			5	17	100	25	SD = .72
5	Use of Experience	ORD	1	0	0	0	Mean = 3
			2	5	7.5	7.5	Median = 3
			3	57	92.5	85	Mode = 3
			4	5	100	7.5	Range = 2-4
			5	0	100	0	SD = .39

APPENDIX F

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
6	Decision-Oriented	ORD	1	0	0	0	Mean = 4
			2	3	4	4	Median = 4
			3	10	19	15	Mode = 4
			4	38	76	57	Range = 2-5
			5	16	100	24	SD = .76
7	Common Sense Use	ORD	1	3	4	4	Mean = 2.75
			2	15	27	23	Median = 3
			3	45	94	67	Mode = 3
			4	4	100	6	Range = 1-4
			5	0	100	0	SD = .64
8	Creativity	ORD	1	1	1	1	Mean = 2.97
			2	15	24	23	Median = 3
			3	38	81	57	Mode = 3
			4	11	99	16	Range = 1-5
			5	2	100	2	SD = .76
9	Mathematical Models	ORD	1	5	7	7	Mean = 2.58
			2	22	40	33	Median = 3
			3	36	94	54	Mode = 3
			4	4	100	6	Range = 1-4
			5	0	100	0	SD = .72
10	Use of Knowledge	ORD	1	0	0	0	Mean = 3.4
			2	6	9	9	Median = 3
			3	31	55	46	Mode = 3
			4	27	95	40	Range = 2-5
			5	3	100	5	SD = .72

APPENDIX F

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
11	Prediction	ORD	1	0	0	0	Mean = 2.40
			2	40	60	60	Median = 2
			3	27	100	40	Mode = 2
							Range = 2-3
							SD = .49
12	Diagnosis	ORD	1	0	0	0	Mean = 2.66
			2	23	34	34	Median = 3
			3	44	100	66	Mode = 3
							Range = 2-3
							SD = .48
13	Debugging	ORD	1	0	0	0	Mean = 2.88
			2	8	12	12	Median = 3
			3	59	100	88	Mode = 3
							Range = 2-3
							SD = .33
14	Instruction	ORD	1	0	0	0	Mean = 2.67
			2	22	33	33	Median = 3
			3	45	100	67	Mode = 3
							Range = 2-3
							SD = .47

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
15	Analysis	ORD	1	2	3	3	Mean = 2.58
			2	24	39	36	Median = 3
			3	41	100	61	Mode = 3
							Range = 1-3
							SD = .55
16	Scheduling	ORD	1	2	3	3	Mean = 2.55
			2	26	42	39	Median = 3
			3	39	100	58	Mode = 3
							Range = 1-3
							SD = .56
17	Fault Isolation	ORD	1	1	1	1	Mean = 2.70
			2	18	28	27	Median = 3
			3	48	100	72	Mode = 3
							Range = 1-3
							SD = .49
18	Target Resource Allocation	ORD	1	5	7	7	Mean = 2.31
			2	36	61	54	Median = 2
			3	26	100	39	Mode = 2
							Range = 1-3
							SD = .61

ANALYSIS -- Intelligence Warrant Officer Sample Data Tabulation and Summary Statistics

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
1	Thinking Process	NML	Common Sense	13	39	39	Mode =
			Experience	20	100	61	Experi-
			Researching	0	100	0	ence
			None of above	0	100	0	
2	Time Factor	NML	< 1 min.	10	30	30	Mode =
			1-59 mins.	21	94	64	1-59mins
			1-3 hours	2	100	6	
			> 3 hours	0	100	0	
3	Use of Facts	NML	Known Facts	4	12	12	Mode =
			Intuition	3	21	9	Facts &
			Both	26	100	79	Intuition
			None	0	100	0	
4	Regularity	ORD	1	0	0	0	Mean = 3.61
			2	1	3	3	Median = 4
			3	15	48	45	Mode = 3
			4	13	88	40	Range = 2-5
			5	4	100	12	SD = .75
5	Use of Experience	ORD	1	0	0	0	Mean = 3
			2	5	15	15	Median = 3
			3	23	85	70	Mode = 3
			4	5	100	15	Range = 2-4
			5	0	100	0	SD = .56

APPENDIX G

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
6	Decision-Oriented	ORD	1	0	0	0	Mean = 3.61
			2	2	6	6	Median = 4
			3	11	39	33	Mode = 4
			4	18	94	55	Range = 2-5
			5	2	100	6	SD = .70
7	Common Sense Use	ORD	1	1	3	3	Mean = 2.97
			2	3	12	9	Median = 3
			3	25	88	76	Mode = 3
			4	4	100	12	Range = 1-4
			5	0	100	0	SD = .59
8	Creativity	ORD	1	1	3	3	Mean = 3.30
			2	2	9	6	Median = 3
			3	20	70	61	Mode = 3
			4	6	88	18	Range = 1-5
			5	4	100	12	SD = .88
9	Mathematical Models	ORD	1	10	30	30	Mean = 1.94
			2	15	75	45	Median = 2
			3	8	100	25	Mode = 2
			4	0	100	0	Range = 1-3
			5	0	100	0	SD = .75
10	Use of Knowledge	ORD	1	0	0	0	Mean = 3.30
			2	3	9	9	Median = 3
			3	18	64	55	Mode = 3
			4	11	97	33	Range = 2-5
			5	1	100	3	SD = .68

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
11	Prediction	ORD	1	1	3	3	Mean = 2.27
			2	22	70	67	Median = 2
			3	10	100	30	Mode = 2
							Range = 1-3
							SD = .52
12	Diagnosis	ORD	1	2	6	6	Mean = 2.30
			2	19	64	58	Median = 2
			3	12	100	36	Mode = 2
							Range = 1-3
							SD = .59
13	Debugging	ORD	1	1	3	3	Mean = 2.48
			2	15	48	45	Median = 3
			3	17	100	52	Mode = 3
							Range = 1-3
							SD = .57
14	Instruction	ORD	1	1	3	3	Mean = 2.56
			2	12	39	36	Median = 3
			3	20	100	61	Mode = 3
							Range = 1-3
							SD = .56

APPENDIX G

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
15	Analysis	ORD	1	2	6	6	Mean = 2.24
			2	21	70	64	Median = 2
			3	10	100	30	Mode = 2
							Range = 1-3
							SD = .56
16	Scheduling	ORD	1	2	6	6	Mean = 2.42
			2	15	51	45	Median = 2
			3	16	100	49	Mode = 3
							Range = 1-3
							SD = .61
17	Fault	ORD	1	2	6	6	Mean = 2.27
	Isolation		2	20	67	61	Median = 2
			3	11	100	33	Mode = 2
							Range = 1-3
							SD = .57
18	Target Resource	ORD	1	7	21	21	Mean = 1.97
	Allocation		2	20	82	61	Median = 2
			3	6	100	18	Mode = 2
							Range = 1-3
							SD = .64

ANALYSIS -- Supply Warrant Officer Sample Data Tabulation and Summary Statistics

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
1	Thinking	NML	Common Sense	3	6	6	Mode =
	Process		Experience	45	96	90	Experi-
			Researching	2	100	4	ence
			None of above	0	100	0	
2	Time	NML	< 1 min.	15	30	30	Mode =
	Factor		1-59 mins.	35	100	70	1-59mins
			1-3 hours	0	100	0	
			> 3 hours	0	100	0	
3	Use of	NML	Known Facts	16	32	32	Mode =
	Facts		Intuition	0	32	0	Facts &
			Both	34	100	68	Intuition
			None	0	100	0	
4	Regularity	ORD	1	0	0	0	Mean = 4.08
			2	0	0	0	Median = 4
			3	10	20	20	Mode = 4
			4	26	72	52	Range = 3-5
			5	14	100	28	SD = .70
5	Use of Experience	ORD	1	2	4	4	Mean = 3.18
			2	1	6	2	Median = 3
			3	34	74	68	Mode = 3
			4	12	98	24	Range = 1-5
			5	1	100	2	SD = .69

APPENDIX H

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
6	Decision-Oriented	ORD	1	0	0	0	Mean = 3.82
			2	0	0	0	Median = 4
			3	17	34	34	Mode = 4
			4	25	84	50	Range = 3-5
			5	8	100	16	SD = .69
7	Common Sense Use	ORD	1	2	4	4	Mean = 2.80
			2	9	22	18	Median = 3
			3	36	94	72	Mode = 3
			4	3	100	6	Range = 1-4
			5	0	100	0	SD = .61
8	Creativity	ORD	1	1	2	2	Mean = 2.90
			2	12	26	24	Median = 3
			3	28	82	58	Mode = 3
			4	9	100	18	Range = 1-4
			5	0	100	0	SD = .71
9	Mathematical Models	ORD	1	3	6	6	Mean = 2.72
			2	16	38	32	Median = 3
			3	23	84	46	Mode = 3
			4	8	100	16	Range = 1-4
			5	0	100	0	SD = .81
10	Use of Knowledge	ORD	1	1	2	2	Mean = 3.46
			2	2	6	4	Median = 3
			3	23	52	46	Mode = 3
			4	21	94	42	Range = 1-5
			5	3	100	6	SD = .76

APPENDIX H

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
11	Prediction	ORD	1	0	0	0	Mean = 2.40
			2	30	60	60	Median = 2
			3	20	100	40	Mode = 2
							Range = 2-3
							SD = .49
12	Diagnosis	ORD	1	1	2	2	Mean = 2.44
			2	26	54	52	Median = 2
			3	23	100	46	Mode = 2
							Range = 1-3
							SD = .54
13	Debugging	ORD	1	0	0	0	Mean = 2.58
			2	21	42	42	Median = 3
			3	29	100	58	Mode = 3
							Range = 2-3
							SD = .50
14	Instruction	ORD	1	0	0	0	Mean = 2.88
			2	6	12	12	Median = 3
			3	44	100	88	Mode = 3
							Range = 2-3
							SD = .33

APPENDIX H

Item	Variable	Scale	Responses	Freq.	Cum/Freq%	%	Stats
15	Analysis	ORD	1	0	0	0	Mean = 2.62
			2	19	38	38	Median = 3
			3	31	100	62	Mode = 3
							Range = 2-3
							SD = .49
16	Scheduling	ORD	1	2	4	4	Mean = 2.62
			2	15	34	30	Median = 3
			3	33	100	66	Mode = 3
							Range = 1-3
							SD = .57
17	Fault Isolation	ORD	1	2	4	4	Mean = 2.54
			2	19	42	38	Median = 3
			3	29	100	58	Mode = 3
							Range = 1-3
							SD = .58
18	Target Resource Allocation	ORD	1	2	4	4	Mean = 2.38
			2	27	58	54	Median = 2
			3	21	100	42	Mode = 2
							Range = 1-3
							SD = .57

APPENDIX H

ANALYSIS -- Personnel Warrant Officers' Sample Profile

Sample Size = 67

Item Number	Profile Element	Data Measurement
1	Thinking Process	Experience
2	Time Factor	1-59 mins.
3	Use of Facts	Facts & Intuition
4	Regularity	4
5	Use of Experience	3
6	Decision-Oriented	4
7	Use of Common Sense	2.75
8	Creativity	2.97
9	Mathematical Models	2.58
10	Use of Knowledge	3.40
11	Prediction	2.40
12	Diagnosis	2.66
13	Debugging	2.88
14	Instruction	2.67
15	Analysis	2.58
16	Scheduling	2.55
17	Fault Isolation	2.70
18	Target Resource Allocation	2.31

APPENDIX I

ANALYSIS -- Intelligence Warrant Officers' Sample Profile

Sample Size = 33

Item Number	Profile Element	Data Measurement
1	Thinking Process	Experience
2	Time Factor	1-59 mins.
3	Use of Facts	Facts & Intuition
4	Regularity	3.61
5	Use of Experience	3
6	Decision-Oriented	3.61
7	Use of Common Sense	2.97
8	Creativity	3.30
9	Mathematical Models	1.94
10	Use of Knowledge	3.30
11	Prediction	2.27
12	Diagnosis	2.30
13	Debugging	2.48
14	Instruction	2.56
15	Analysis	2.24
16	Scheduling	2.42
17	Fault Isolation	2.27
18	Target Resource Allocation	1.97

ANALYSIS -- Supply Warrant Officers' Sample Profile

Sample Size = 50

Item Number	Profile Element	Data Measurement
1	Thinking Process	Experience
2	Time Factor	1-59 mins.
3	Use of Facts	Facts & Intuition
4	Regularity	4.08
5	Use of Experience	3.18
6	Decision-Oriented	3.82
7	Use of Common Sense	2.80
8	Creativity	2.90
9	Mathematical Models	2.72
10	Use of Knowledge	3.46
11	Prediction	2.40
12	Diagnosis	2.44
13	Debugging	2.58
14	Instruction	2.88
15	Analysis	2.62
16	Scheduling	2.62
17	Fault Isolation	2.54
18	Target Resource Allocation	2.38

APPENDIX K

ANALYSIS -- Comparison of Sample Populations

Item #	Model Variable	Model Measure	Personnel	Intelligence	Supply
1	Thinking Process	Experience/ Research	Y	Y	Y
		Use of Facts	N	N	N
		No Common Sense	Y	Y	Y
		No Mathematical Models	Y	Y	Y
2	Decision Characteristics	1min-3 hrs	Y	Y	Y
		Routine Decisions	Y	Y	Y
		Not Creative	Y	N	Y
3	Functions	Use of Knowledge	Y	Y	Y
		Decision-Oriented	Y	Y	Y
		Prediction/	N	N	N
		Diagnosis/	Y	N	N
		Debugging/	Y	N	Y
		Instruction/	Y	Y	Y
		Analysis/	Y	N	Y
		Scheduling/	Y	N	Y
		Fault Isolation/	Y	N	Y
		Target Resource	N	N	N

APPENDIX L